Mediterranean Journal of Pharmacy & Pharmaceutical Sciences
ISSN: 2789-1895 online
www.medjpps.com
doi: 10.5281/zenodo.21719557
ISSN: 2958-3101 print

ORIGINAL RESEARCH article

Knowledge, handling practices, and systemic challenges regarding safe chemotherapy management among Libyan healthcare providers in Benghazi

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Received: 23-05-2026, **Accepted**: 28-07-2026, **Published online:** 00-08-2026

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HOW TO CITE THIS

Salama RM, Elfakhri RM. Knowledge, handling practices, and systemic challenges regarding safe chemotherapy management among Libyan healthcare workers in Benghazi. Mediterr J Pharm Pharm Sci. 2026; 6(3): 22-32. [Article number: 258]. https://doi.org/10.5281/zenodo.21719557

Keywords: Chemotherapy safety, hazardous drugs, healthcare providers, pharmacist, occupational exposure

Abstract: Healthcare professionals handling chemotherapy drugs are at occupational risk if proper precautions are not taken. Despite international recommendations for the safe handling of hazardous drugs, data on healthcare providers' knowledge, handling practices, and challenges in Libya are limited. The study aimed to assess the knowledge and safe handling practices of healthcare providers regarding chemotherapy in two hospitals in Benghazi, Libya, and identify factors associated with safe handling practices. A cross-sectional study was conducted between October 2024 and August 2025 among pharmacists and nurses at Benghazi Medical Centre and Children's Hospital. Participants completed a questionnaire on demographics, knowledge, handling practices, and workplace challenges. Non-parametric tests and Cronbach's alpha were used to analyse the data and assess questionnaire reliability. A total of 56 healthcare workers participated. Respondents demonstrated partial understanding of chemotherapy-related concepts, with 21.4% achieving good knowledge, and over one-third demonstrating poor knowledge. Pharmacists scored significantly higher than nurses ($p = 0.001$). Half of the participants reported safe handling practices, and previous chemotherapy safety training was significantly associated with higher practice scores ($p = 0.022$). Participants showed good knowledge of general chemotherapy principles but limited knowledge of oral chemotherapy and protective glove use. The main challenges identified were heavy workload (85.7%), lack of management support (66.1%), and inadequate chemotherapy training (64.3%). The knowledge and practice scales demonstrated modest (Cronbach's $\alpha = 0.548$) and good (Cronbach's $\alpha = 0.717$) reliability, respectively. Healthcare providers demonstrated acceptable handling practices but insufficient knowledge of chemotherapy safety and reported limited organisational support. Regular training, stronger institutional support, and clear policies are needed to improve the safe handling of chemotherapy in Libya.

Introduction

Cancer is one of the leading causes of morbidity and mortality and a major threat to human health. According to the Global Cancer Observatory (GLOBOCAN 2022), approximately 20 million new cancer cases and 9.7 million cancer-related deaths occurred worldwide in 2022. Furthermore, the global cancer burden is expected to increase because of population growth, population ageing, and changes in cancer risk factors [1]. Today, the safe handling of chemotherapy is one of the greatest challenges faced by healthcare workers administering antineoplastic agents [2]. According to international guidelines, antineoplastic agents are considered

hazardous drugs because of their genotoxic, carcinogenic, teratogenic, and reproductive effects [3]. Therefore, they require appropriate handling in healthcare facilities to protect healthcare workers, patients, and the environment [4]. Safe chemotherapy management involves evidence-based protocols for receiving, storing, preparing, dispensing, transporting, administering, decontaminating, and disposing of antineoplastic agents [5]. It requires healthcare professionals to have sufficient knowledge to implement evidence-based handling instructions and institutional compliance with chemotherapy safety policies and a safety culture [4, 5]. Many international organizations have developed evidence-based recommendations for the safe handling of chemotherapy [1-3]. The National Institute for Occupational Safety and Health (NIOSH), United States Pharmacopeia (USP), Oncology Nursing Society (ONS), Occupational Safety and Health Administration (OSHA), and American Society of Health-System Pharmacists (ASHP) recommend engineering controls, standard operating procedures, education and training, and environmental monitoring to reduce occupational exposure [2-6]. However, ensuring the safe management of chemotherapy remains challenging, particularly in low- and middle-income countries. Several studies have reported inadequate knowledge of antineoplastic hazards, poor compliance with recommended handling practices, limited educational resources, and inadequate institutional support, particularly in developing countries [7-9]. Therefore, it is vital to provide healthcare professionals with the required knowledge and competencies and to offer institutional support for establishing efficient, safe management systems for chemotherapy.

Materials and methods

Study design and setting: The cross-sectional descriptive study was conducted between October 2024 and August 2025 to determine healthcare workers' knowledge and safe handling practices, and the perceived system barriers while managing chemotherapy in Benghazi Medical Centre (BMC) and Children's Hospital. They represent the biggest hospitals in Benghazi that provide specialized forms of care, including the preparation, dispensation, administration, transportation, and disposal of cytotoxic drugs. This study was designed and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational studies [10, 11].

Study population and sampling: All healthcare workers directly involved in receiving, storing, preparing, dispensing, transporting, administering, or disposing of cytotoxic drugs were eligible to participate in the study. The selected population comprised pharmacists and nurses with at least six months of experience in chemotherapy services. Those not involved in any of the above-described activities and those declining to participate were excluded from the study.

Questionnaire design: The questionnaire was designed upon a thorough literature review and international recommendations for the safe handling of hazardous drugs [2, 3]. A search of databases revealed several questionnaires used to measure knowledge, chemotherapy-handling practices, occupational safety, and institutional preparedness with acceptable psychometric properties [12-16]. The questionnaire was translated into Arabic to ensure participants' comprehension and then evaluated by the research team. The final version included six sections: Demographic data, knowledge, safe handling practices, availability and utilization of personal protective equipment (PPE), occupational exposure and health, and workplace challenges. The demographic data, knowledge, practice, and systemic challenge sections were analysed in this study. The demographic section gathered the participants' age, gender, profession, educational qualification, marital status, place of work, years of experience, and prior training in chemotherapy safety. The knowledge section contained ten true/false/I do not know statements related to knowledge of hazardous drugs, routes of exposure to chemotherapeutic agents, characteristics of chemotherapy, and safety practices. Statements were scored as True (1) when participants selected true responses and False (0) when participants selected false or I do not know responses. The total score ranged from 0 to 10 with the following interpretation: poor (score < 6), fair (score 6 - 7.9), and good (score ≥ 8) based on modified Bloom's cut-off criterion [17].

The safe handling practices comprised ten items evaluating chemotherapy preparation, administration, transportation, storage, spill management, waste disposal, and compliance with institutional safety guidelines [10, 14, 18]. The response options ranged from always, sometimes, and never, with corresponding scores of 2, 1, and 0. One item regarding reusing disposable PPE was reverse-scored. The practice scores ranged between 0 and 20 and were categorized as unsafe (< 12), moderate (12 - 15), and safe (> 15) according to the modified Bloom's cut-off criteria [18, 19]. In addition, a multiple-response question on workplace challenges about organizational toxicology related to chemotherapy management was included.

Validity and reliability: The questionnaire was evaluated by a panel of experts in pharmaceutics, clinical pharmacy, oncology, nursing, and research methodology to establish content validity. The instrument was tested for face validity by administering it to healthcare workers similar to the target population, reviewing the results, and making necessary improvements. The pilot study responses were excluded from the final analysis. The questionnaire's reliability was determined using Cronbach's alpha coefficient, while the item-total correlations were computed to establish individual items' contributions towards the overall knowledge and practice scores [18, 19].

Data collection procedure: The questionnaires were administered to eligible participants after obtaining informed consent from them. The participants were allowed to complete the questionnaires on their own during working hours. Finally, the completed forms were checked for completeness, coded, and entered into the Statistical Package for the Social Sciences (SPSS) for statistical analyses.

Ethical considerations: All questionnaires were anonymous, and no identifying or sensitive information was collected from participants (019-MJ-2106-07). All participants provided verbal informed consent before completing the questionnaire. No rewards were given to the participants for their involvement in the study.

Statistical analysis: Descriptive statistics were used to summarize demographic variables and questionnaire items. Categorical variables were presented as frequencies and percentages, while knowledge and practice scores were reported as medians and interquartile ranges (IQRs). Mann-Whitney U-test and Kruskal-Wallis test were used to compare scores between the groups. A p-value < 0.05 was considered significant.

Results

Data collection and demographic characteristics of participants: Out of 59 healthcare workers, 57 participated (Response rate: 96.6%; pharmacists 93.9%, nurses 100%), with one questionnaire excluded. Most participants were females (83.9%), aged 20 - 40 years, held a diploma (42.9%) or bachelor's degree (50.0%), and were married (57.1%). Pharmacists presented 55.4% of the sample, 75.0% worked at BMC, 44.6 % had less than five years of chemotherapy experience, and 53.6% had received previous training (**Table 1**). About the reliability, the internal consistency of the questionnaire was tested using Cronbach's alpha. The knowledge and practice scales (10 items each) showed a Cronbach's α of 0.548 and 0.717, respectively.

Knowledge levels of participants: Overall, 21.4% of respondents demonstrated good knowledge, 42.9% moderate knowledge, and 35.7% poor knowledge (**Table 2**). Pharmacists showed higher levels of knowledge than nurses, with 29.0% demonstrating good knowledge compared with 12.0% of nurses. In contrast, poor knowledge was more common among nurses (56.0%) than pharmacists (19.4%). The highest correct response rates are presented in **Table 3**. The highest correct response rates were for the question on chemotherapy administration routes (96.8% of pharmacists and 96.0% of nurses), followed by the question identifying fatigue as a common side effect of chemotherapy (93.5% and 84%, respectively). The lowest correct response rates were for the question on the safety of oral chemotherapy compared to IV chemotherapy (16.1% of pharmacists and 12.0% of nurses), followed by the statement that all glove types provide the same level of protection (41.9% of pharmacists and 20.0% of nurses).

Table 1: Demographic characteristics of the Libyan participants

Characteristics	Category	Frequency	Percentage
Gender	Male	09	16.1
	Female	47	83.9
Age (years)	20 - 30	19	33.9
	31 - 40	19	33.9
	41 - 50	16	28.6
	> 50	02	03.6
Marital status	Married	32	57.1
	Unmarried	24	42.9
Qualification	Primary	04	07.1
	Diploma	24	42.9
	BSc	28	50.0
Profession	Pharmacist	31	55.4
	Nurse	25	44.6
Workplace	BMC	42	75.0
	Children's Hospital	14	25.0
Experience (years)	< 5	25	44.6
	5 - 10	15	26.9
	11 - 15	11	19.6
	> 15	05	08.9
Previous training	Yes	30	53.6
	No	26	46.4
Total		**56**	**100.0**

Table 2: Knowledge levels among pharmacists and nurses

Knowledge level	Pharmacists, n (%)	Nurses, n (%)	Total, n (%)
Good	09 (29.0)	03 (12.0)	12 (21.4)
Fair	16 (51.6)	08 (32.0)	24 (42.9)
Poor	06 (19.4)	14 (56.0)	20 (35.7)

Table 3: Correct responses to knowledge questions among pharmacists and nurses

Question	Pharmacists, n (%)	Nurses, n (%)
All types of gloves provide the same level of protection.	13 (41.9)	05 (20.0)
Unlike intravenous chemotherapy, oral chemotherapy is safe to handle.	05 (16.1)	03 (12.0)
Long-term exposure to chemotherapy can be associated with serious risks such as birth defects, reproductive losses, and cancer later in life.	27 (87.1)	11 (44.0)
Some types of cancer are contagious.	27 (87.1)	20 (80.0)
Chemotherapy may be given by mouth, injection, infusion, or on the skin, depending on the type and stage of cancer being treated.	30 (96.8)	24 (96.0)
Tiredness (fatigue) is one of the most common side effects of chemotherapy.	29 (93.5)	21 (84.0)
A surgical mask does not offer sufficient respiratory protection when dealing with chemotherapy.	22 (71.0)	18 (72.0)
Chemotherapy cannot enter the body through contact with contaminated surfaces.	18 (58.1)	10 (40.0)
Chemotherapy can enter the body through contaminated food and drinks.	22 (71.0)	12 (48.0)
There is no risk of exposure when touching oral chemotherapy with bare hands.	20 (64.5)	15 (60.0)

Practice Levels of Participants: Overall, 50.0% of respondents showed safe practice, 28.6% moderate practice, and 21.4% unsafe practice (**Table 4**). Safe practice was slightly more common among nurses (52.0%) than

pharmacists (48.4%). Individual practice items are presented in **Table 5.** Hand hygiene before and after handling chemotherapy showed the highest adherence among pharmacists (74.1%) and nurses (92.0%). Among pharmacists, the lowest adherence was for using designated chemotherapy areas and changing contaminated PPE immediately (45.2% each). Among nurses, the lowest adherence was for wearing two pairs of gloves (48.0%) and appropriate PPE (56.0%).

Table 4: Practice levels among pharmacists and nurses

Practice level	Pharmacists, n (%)	Nurses, n (%)	Total, n (%)
Safe/Good	15 (48.4)	13 (52.0)	28 (50.0)
Moderate	07 (22.6)	09 (36.0)	16 (28.6)
Unsafe/Poor	09 (29.0)	03 (12.0)	12 (21.4)

Table 5: Practices in handling chemotherapy among pharmacists and nurses

Practice	Pharmacists (n = 31)			Nurses (n = 25)		
	Always, n (%)	Sometimes, n (%)	Never, n (%)	Always, n (%)	Sometimes, n (%)	Never, n (%)
Wash hands before and after handling chemotherapy.	23 (74.1)	06 (19.4)	02 (6.5)	23 (92.0)	01 (4.0)	01 (4.0)
Wear two pairs of gloves when dealing with hazardous drugs.	17 (54.8)	06 (19.4)	08 (25.8)	12 (48.0)	08 (32.0)	05 (20.0)
Avoid eating or drinking where chemotherapy is handled.	23 (74.1)	06 (19.4)	02 (6.5)	18 (72.0)	03 (12.0)	04 (16.0)
Wear appropriate personal protective equipment when handling chemotherapy.	16 (51.6)	06 (19.4)	09 (29.0)	14 (56.0)	04 (16.0)	07 (28.0)
Reuse disposable personal protective equipment.	02 (6.5)	06 (19.4)	23 (74.1)	08 (32.0)	00 (0.0)	17 (68.0)
Prepare or administer chemotherapy in designated areas only.	14 (45.2)	03 (9.6)	14 (45.2)	21 (84.0)	00 (0.0)	04 (16.0)
Immediately change contaminated personal protective equipment after contact with chemotherapy.	16 (51.6)	06 (19.4)	09 (29.0)	21 (84.0)	01 (4.0)	03 (12.0)
Segregate cytotoxic waste before disposal and dispose of it correctly and safely.	14 (45.2)	05 (16.1)	12 (38.7)	18 (72.0)	05 (20.0)	02 (8.0)
Use clear labels and packages during storage, preparation, or transportation.	23 (74.1)	02 (6.5)	06 (19.4)	20 (80.0)	01 (4.0)	04 (16.0)
Follow standard guidelines and safety instructions when handling chemotherapy.	16 (51.6)	08 (25.8)	07 (22.6)	17 (68.0)	05 (20.0)	03 (12.0)

Association of knowledge and practice scores with demographic characteristics: The median scores of knowledge and practice were 6 (5 - 7) and 15 (13 - 18), respectively. Further analysis revealed a significant difference in knowledge scores according to gender, with males scoring higher than females (median 7 (7 - 8) vs. 6 (5-7), $p = 0.005$), according to profession, with pharmacists scoring higher than nurses (median 7 (6 - 8) vs. 5 (4 - 6), $p = 0.001$), and according to workplace, with Children's Hospital staff scoring higher than BMC staff (median 7.5 (6.75 - 9.25) vs. 6 (5-7), $p = 0.001$). No significant association was found with age, marital status, previous training, or experience ($p > 0.05$). Level of education showed no significant association with knowledge scores ($p = 0.057$). However, the result was close to the conventional significance threshold, with BSc holders having the highest median score (7) compared with participants with diplomas (6) and primary education (4.5) (**Table 6**). Practice scores differed significantly by workplace, with BMC staff scoring higher than Children's Hospital staff (median 16 (13 - 18) vs. 14 (10.5 - 15.25), $p = 0.025$), and by previous chemotherapy training, with trained participants scoring higher than untrained ones (median 16 (14 - 18) vs.

13.5 (10 - 17), p = 0.022). No other demographic characteristics showed a significant association with practice scores (p > 0.05) (**Table 7**).

Table 6: Comparison of knowledge scores according to participants' demographic characteristics

Characteristics	Category	Knowledge score, median (IQR)	Test statistic	df	P-value
Gender	Male	7 (7-8)	87	1	**0.005**
	Female	6 (5-7)			
Age (years)	20 - 30	7 (5-7)	2.177	3	0.537
	31 - 40	7 (5-7)			
	41 - 50	5.5 (4.25-7)			
	> 50	7 (6-NA)			
Marital status	Married	7 (5-7)	393	1	0.879
	Unmarried	6 (5.7-75)			
Qualification	Primary education	4.5 (4-6.5)	5.74	2	0.057
	Diploma	6 (5-7)			
	BSc	7 (5.25-7.75)			
Profession	Pharmacist	7 (6-8)	192.5	1	**0.001**
	Nurse	5 (4-6)			
Workplace	BMC	6 (5-7)	465.5	1	**0.001**
	Children's Hospital	7.5 (6.75-9.25)			
Previous training	Yes	6 (5-7)	364	1	0.814
	No	6 (5-7)			
Years of experience	< 5	7 (5-7)	1.166	3	0.761
	5 - 10	5 (5-7)			
	11 - 15	6 (5-7)			
	> 15	7 (3-9)			

Data are presented as median. The 75th percentile was not calculated for the > 50 years age group because of the small number of participants in this category (n = 2). P-values were calculated using the Mann-Whitney U test for comparisons between two groups and the Kruskal-Wallis test for comparisons among three or more groups. Statistical significance was set at p < 0.05; significant p-values are shown in bold.

Table 6: Comparison of practice scores according to participants' demographic characteristics

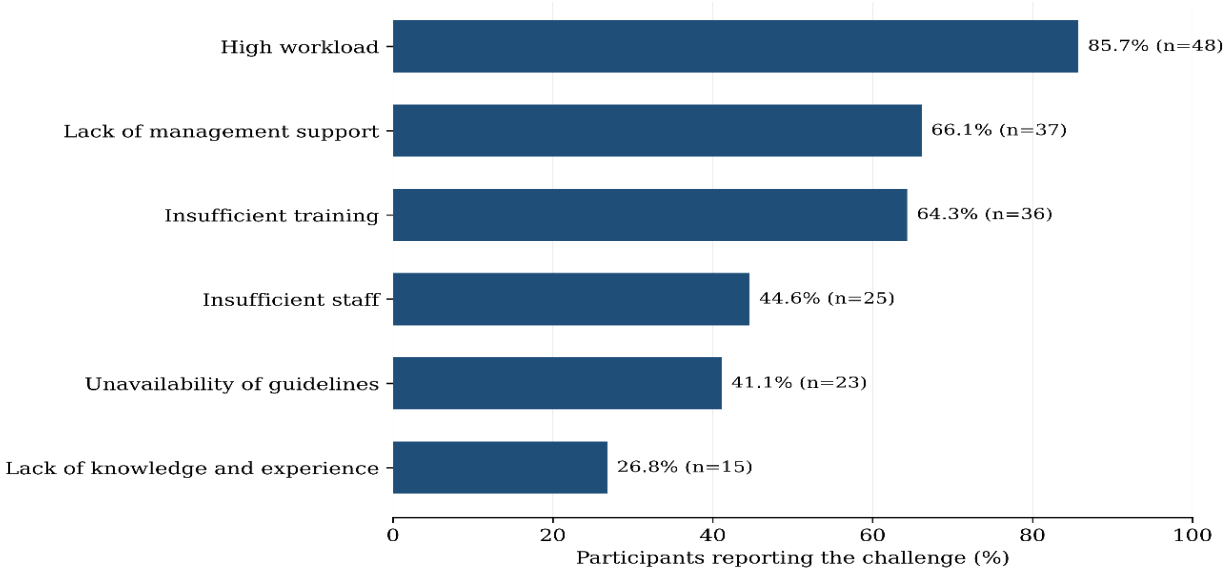
Characteristics	Category	Practice score, median (IQR)	Test statistic	df	P-value
Gender	Male	15 (12-16)	247	1	0.425
	Female	16 (13-18)			
Age (years)	20-30	17 (15-18)	6.319	3	0.097
	31-40	15 (9-18)			
	41-50	14 (10.25-17)			
	>50	13.5 (13-NA)			
Marital status	Married	15.5 (11-17)	450	1	0.271
	Unmarried	16 (13-18)			
Qualification	Primary education	15 (12-17)	1.514	2	0.469
	Diploma	15 (13-18)			
	BSc	15.5 (9.25-17)			
Profession	Pharmacist	15 (10-17)	465	1	0.199
	Nurse	16 (13.5-18)			
Workplace	BMC	16 (13-18)	176.5	1	**0.025**
	Children's Hospital	14 (10.5-15.25)			

Characteristics	Category	Practice score, median (IQR)	Test statistic	df	P-value
Previous training	Yes	16 (14-18)	223.5	1	**0.022**
	No	13.5 (10-17)			
Years of experience	< 5	16 (13-18)	3.25	3	0.353
	5 - 10	16 (13-17)			
	11 - 15	15 (11-18)			
	> 15	10 (3.5-17)			

Data are presented as median. The 75th percentile was not calculated for the > 50 years age group because of the small number of participants in this category (n = 2). P-values were calculated using the Mann-Whitney U test for comparisons between two groups and the Kruskal-Wallis test for comparisons among three or more groups. Statistical significance was set at $p < 0.05$; significant p-values are shown in bold.

Challenges and perceived barriers: The primary barriers to safe practice identified by pharmacists and nurses were high workload (85.7%), insufficient management support (66.1%), and absence of specific training (64.3%). Insufficiency of related knowledge and experience was perceived as the least challenging (26.8%), and only a minor number of respondents (7.0%) reported no challenges being encountered (**Figure 1**).

Figure 1: Overall systemic challenges affecting safe chemotherapy management



Discussion

Extensive studies in the Middle East and North Africa (MENA) region reported limited knowledge, poor compliance, and a lack of standardized safety protocols among healthcare workers [12, 14, 15]. A study at the Sabha Oncology Centre in Libya revealed that implementing chemotherapy guidelines significantly improved oncology nurses' knowledge and practices [16]. These studies highlight the need for education, institutional support, and an efficient chemotherapy safety program. While these findings may not be generalized due to different hospital settings, similar issues might be found in Libya. This study assessed the knowledge and practices of pharmacists and nurses regarding chemotherapy and its safe handling, and identified potential challenges in two main hospitals in Benghazi, Libya. The results may contribute to institutional policies and national strategies for improving chemotherapy safety and quality of cancer care in Libya. The reliability of the study questionnaire was assessed before interpreting the results. The diverse knowledge scale showed modest internal consistency (Cronbach's $\alpha = 0.548$), which is expected as it reflects the knowledge domains assessed. While the practice scale showed good internal consistency (Cronbach's $\alpha = 0.717$), indicating satisfactory reliability [19].

The current study revealed a critical knowledge gap, with only 21.4% of participants demonstrating good knowledge, while 78.6% showed moderate or poor knowledge, which is considered insufficient for dealing with highly hazardous agents that may compromise the safety of chemotherapy handling. Similar findings have been reported in several low- and middle-income countries such as Ethiopia, Iraq, Jordan, Egypt, the Kurdistan region of Iraq, Sudan, and Pakistan [12-16, 20-23]. Apart from the Pakistani study, which used a mixed methodology [23], these studies used similar methodologies, allowing direct comparison. The analysis of item-specific knowledge showed that knowledge varied according to different chemotherapy topics. Pharmacists and nurses showed good knowledge of routine clinical practice related to chemotherapy. The highest number of correct responses was for the routes of administration of chemotherapy (96.8% pharmacists and 96.0% nurses), followed by the recognition of common chemotherapy side-effects (93.5% pharmacists and 84.0% nurses). These high scores are probably because participants frequently encounter these topics in their practice. In contrast, knowledge of participants was poorest regarding chemotherapy safety precautions. Less than half of pharmacists (41.9%) and 20.0% of nurses correctly recognised that gloves vary in their level of protection, and 16.1% of pharmacists and 12.0% of nurses knew that oral chemotherapy should be handled the same as other chemotherapy types. These findings can be supported by the study conducted by Ibrahim et al., who revealed that health care workers lacked knowledge of oral chemotherapy and often failed to use the necessary precautions when handling it [24]. International authorities, including NIOSH, USP <800>, and the Oncology Nursing Society, recommend handling oral chemotherapy the same as injectable chemotherapy and advise using chemotherapy-resistant gloves when handling hazardous drugs [2-4].

Although many participants showed limited knowledge, half of them showed safe practice, 28.6% moderate practice, and 21.4% unsafe practice. These results are consistent with a study done at Kenyatta National Hospital, where respondents scored: 49.5% good, 33.9% fair, and 16.5% poor practices [25]. The current study found that 52.0% of the nurses demonstrated slightly better practice compared to 48.4% of pharmacists. While this difference remains small, both participants still require improvement. This difference suggests that regular daily work helps create stronger practical habits without a good grasp of the theory behind chemotherapy safety. This study's results support similar studies that have been conducted elsewhere, including a study conducted in Sudan [21], which found that healthcare workers had acceptable handling practices even though they had limited knowledge of chemotherapy safety. Similarly, the study also concurs with earlier findings that good handling practices do not necessarily translate to a good level of knowledge [13, 22, 23]

One of the key observations made in this study was the difference in adherence to individual safe-handling practices between pharmacists and nurses. While both occupational groups demonstrated overall compliance with most of the recommended precautionary measures, nurses tended to be slightly safer in terms of hand hygiene and use of PPE. Hand hygiene was consistently performed by a higher percentage of nurses than pharmacists (92.0% vs. 74.1%, respectively). This rate is significantly higher than those previously reported among oncology nurses and in Egypt and the Kurdistan Region of Iraq in similar settings [20, 26]. Thus, while these figures cannot be directly compared due to methodological differences between the studies, they indicate that healthcare workers in the current study were safer in terms of hand hygiene than many of their international counterparts. By contrast, consistent use of PPE was lower, being reported by only 51.6% of pharmacists and 56.0% of nurses, with 54.8% of pharmacists and 48.0% of nurses always wearing double chemotherapy gloves. Similar rates of PPE use have been reported by Lawson et al. [27] and Martin and Larson [28] for healthcare workers handling cytotoxic drugs. Notably, while the workers were likely to wear gloves, the use of other elements of PPE was inconsistent with recommendations. According to NIOSH, USP<800>, and the Oncology Nursing Society guidelines, chemotherapy-tested gloves and protective clothing should be worn when preparing or administering hazardous drugs to reduce the risk of occupational exposure [2-4]. Therefore, the rates observed in the current study suggest that there is a chance for improvement in this area, particularly in terms of consistent use of all elements of PPE. There were also notable differences between pharmacists and nurses in accordance with other safe-handling practices. For

instance, nurses were significantly more likely to remove contaminated PPE promptly (84.0% vs. 51.6%), prepare/administer in designated areas (84.0% vs. 45.2%), correctly dispose of chemotherapy waste (72.0% vs. 45.2%), and consistently adhere to workplace safety guidelines (68.0% vs. 51.6%). The reasons for this gap were probably twofold: differences in work between pharmacists and nurses, and the fact that nurses received more on-the-job training and supervision. At the same time, the lower adherence to safe-handling practices among pharmacists suggests that they could benefit from additional education and support. On the other hand, a large majority of nurses (74.1%) and pharmacists (72.0%) always avoided eating and drinking in areas where chemotherapy was prepared/administered, thus protecting themselves from inadvertent drug exposure. This is a significantly higher percentage than that previously reported study of Egyptian oncology nurses, where 50.0% avoided eating in chemotherapy preparation areas, and 33.3% reported drinking in these areas [26]. In addition, most workers in the current study always adhered to proper segregation of chemotherapy drugs from other medications during storage, preparation, and transport, which further reduced their risk of exposure.

The main challenge reported by participants in this study was high workload, followed by lack of management support and insufficient training. This aligns with similar studies, which reported heavy workload being the most encountered challenge [14, 26]. These challenges may contribute to the gaps in safe practices, and the findings suggest the need for not only education for improving chemotherapy safety, but also institutional support and continuous training. Even though overall knowledge and practice levels offer a general perspective on chemotherapy safety awareness, variations among health care workers may be affected by professional or demographic factors [29-31]. Therefore, the current study investigated the associations between these factors and scores of knowledge and practice. Gender was significantly associated with knowledge, with males demonstrating higher knowledge than females (median 7 vs 6). Males in this study made up only 16.1% of the total sample, reflecting the typical female dominance in pharmacy and nursing worldwide. Due to the small number of males in this study, their average score was probably affected by a few highly educated males. In addition, profession is significantly associated with knowledge scores, with pharmacists achieving higher scores than nurses (Median 7 vs 5). This finding is not unexpected, as it is common for pharmacists to have better knowledge and understanding of drug administration, handling, and dispensing than nurses, who have more limited expertise in this area of healthcare [4, 5, 12]. To bridge this gap, hospitals should introduce inter-professional training where pharmacists teach nurses regarding the safe handling and risks associated with handling chemotherapy. Even though slightly more than half of the respondents claimed to have received previous training, this study revealed that earlier training significantly improved the health workers' practices; however, not their level of knowledge. This suggests that previous training initiatives successfully taught practical skills, but failed to ensure long-term memory of theory. Even though safe practice is a vital outcome, practicing with the lack of essential knowledge can be potentially harmful. The workplace was significantly associated with both knowledge and practice, revealing a distinct difference between the two hospitals. At BMC, respondents demonstrated better practice but worse knowledge, implying strict enforcement of safety protocols without strengthening theoretical understanding. In contrast, the Children's Hospital showed better knowledge but worse practice, suggesting that health care workers in this hospital gained more effective theoretical training but faced practical barriers. This is consistent with the finding that more than two-thirds of the staff at this hospital reported high workload, insufficient staff, and lack of management support as the three main barriers they encountered. The knowledge and practice gaps indicate that formal education or training alone is insufficient for chemotherapy safety. As guidelines evolve, ongoing training becomes essential. Moreover, consistent with global studies [12-16, 20-23, 32, 33], our findings support the need for ongoing education and training on chemotherapy safety as recommended by NIOSH, USP<800>, the Oncology Nursing Society, OSHA, and AHSP [2-6].

Conclusion: In general, pharmacists demonstrated better knowledge than nurses. Healthcare workers who received safety training reported better handling practices. High workload, lack of managerial support, and inadequate training opportunities were identified as the primary hindrances to safe handling. This study established knowledge, experience, and the receipt of safety training as key contributors to safe handling practices. The study contributes to the existing literature by providing insights into the handling practices of healthcare workers in Benghazi, Libya, and can serve as a foundation for future research or interventions seeking to improve institutional policies regarding the safe handling of chemotherapy.

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Acknowledgements: The authors would like to express their gratitude to the administration and staff of Benghazi Medical centre and the Children's Hospital for their cooperation and support throughout this study. Special appreciation is extended to all the pharmacists and nurses who generously participated and shared their time and experiences. We also acknowledge with great appreciation Amna A. Breibish, Aya S. Almogassapi, Fatma A. Al-Zanatie, Issra M. Elhamaly, & Nour J. Elnaili for their dedicated efforts and active involvement in data collection and fieldwork. The authors also thank Dr. Faisa S. Alzuni for her valuable advice and assistance with the statistical analysis.

Authors' contribution: RMS conceived and designed the study. Both contributed equally, approved the final version of the manuscript, and agreed to be accountable for its contents.

Conflict of interest: The authors declare the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Ethical issues: The authors have considered ethical issues, including plagiarism, informed consent, data fabrication or falsification, and double publication or submission.

Data availability statement: The raw data that support the findings of this article are available from the corresponding author upon reasonable request.

Generative AI disclosure: No Generative AI was used in the preparation of this manuscript.